29. Evaluation of Hastelloy N for SNAP-8 Service

H. E. McCoy, Jr.

J. R. Weir, Jr.

The SNAP-8 is an electrical-generating system being developed for use in future space vehicles. The reactor is NaK cooled, fueled and moderated with zirconium hydride containing ^{235}U , and reflected with beryllium. The fuel element uses Hastelloy N as a cladding material, and some concern has developed over the mechanical properties of Hastelloy N in a nuclear environment. Our previous work has shown that this material was subject to a type of high-temperature radiation damage that resulted in reduced rupture life and ductility.^{1,2} Although these changes are undesirable, they do not necessarily rule out the use of a material. Hence, one of our roles in this program has been to determine the magnitudes of the property changes during irradiation, so that the designers can decide whether Hastelloy N can be utilized in a nuclear system of the proposed type. A second objective was to seek ways of improving the properties by thermal-mechanical treatments or by changes in alloy composition. This program is closely related to part of the work described in Chap. 34, Molten-Salt Reactor Program. Related electron microscopy is reported in Part I, Chap. 5 of this report.

The first experiments on standard vacuum-melted Hastelloy N involved small tensile specimens with a gage section $\frac{1}{8}$ in. diam $\times$ $1\frac{1}{8}$ in. long that were irradiated and then subjected to tensile and creep tests. These specimens were irradiated to a thermal dose of 2.3×10^{20} neutrons/cm² at 650 and 760°C and tested at the irradiation temperature. Two heats

of material in several metallurgical conditions were used. The fracture ductility is shown as a function of strain rate in Fig. 29.1; both creep and tensile test results are included in this plot.³ At 650°C the ductility depended upon strain rate; fracture strains of up to 11% were obtained in a slow-strain tensile test. At 760°C the fracture ductility was only 1.0 to 1.5% in a tensile test but did not decrease much further with decreasing strain rate. For both test temperatures the ductility went through a minimum of about 0.5% at a strain rate of about 0.5%/hr. As the stress decreased with an attendant decrease in the strain rate, the rupture ductility increased so strains of a few percent were obtained at low strain rates. The ductility of unirradiated specimens ranged from 15 to 30% for all test conditions investigated. Other significant conclusions from these experiments are:

1. At 760°C the rupture life was decreased by irradiation about two orders of magnitude at high stresses. The stress-rupture curves for irradiated and unirradiated specimens converged slightly with decreasing stress.
2. At 760°C, the minimum creep rate at high stresses was reduced by irradiation but was the same for irradiated and unirradiated specimens at stresses below about 10,000 psi.
3. At 650°C, the rupture life was decreased by irradiation only about one order of magnitude, and sufficient data were not available to make a conclusion about convergence at low stresses.
4. At 650°C, the minimum creep rate was unaffected by irradiation.

¹W. R. Martin and J. R. Weir, "Effect of Elevated Temperature Irradiation on the Strength and Ductility of the Nickel-Base Alloy, Hastelloy N," *Nucl. Appl.* 1, 160 (1965).

²W. R. Martin and J. R. Weir, "Postirradiation Creep and Stress Rupture of Hastelloy N," *Nucl. Appl.* 3, 167 (1967).

³The metallurgical conditions identified symbolically on the graph will be explained by H. E. McCoy, Jr., *Effects of Irradiation on the Mechanical Properties of Two Vacuum-Melted Heats of Hastelloy N*, report in preparation.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Fig. 29.1. Fracture Ductilities for Hastelloy N Under Several Test Conditions.

5. None of the metallurgical variables studied (two heats and various metallurgical states) appeared to significantly affect the postirradiation properties.

Since the service application involves tubes about $\frac{1}{2}$ in. in diameter, we ran several experiments where tubes were pressurized in the reactor.⁴ The failure time and the strain at fracture were obtained by this technique. The thermal flux was 4×10^{13} neutrons $\text{cm}^{-2} \text{sec}^{-1}$, and the temperature was 760°C . Several significant observations were made in this study.

1. The rupture life was reduced by about an order of magnitude when the thermal-neutron dose was only of the order of 10^{18} neutrons/ cm^2 . The stress-

rupture curves of the irradiated and unirradiated materials remained parallel.

2. The tangential rupture strains decreased from values of 7 to 10% for the unirradiated tubes to 0.1 to 2% for the irradiated tubes.
3. The creep rates were estimated and appeared to be unaffected by irradiation.

The results of the tests on rods and tubes were compared. The differences in properties could be accounted for on the basis of differences in stress state and dose at the time of failure.

The properties of Hastelloy N were improved significantly by slight changes in chemical composition. Additions of about 0.5% Ti, Zr, and Hf were studied individually, and each produced improved properties under SNAP-8 operating conditions. The details of this work are discussed in Chap. 34.

⁴H. E. McCoy, Jr., and J. R. Weir, Jr., *In- and Ex-Reactor Stress-Rupture Properties of Hastelloy N Tubing*, ORNL-TM-1906 (to be published).